EE 320 Electronics

Feb. 24

lecture 9

Q4

a) N-type

b) $N = 10^{16}$ electrons/cm3 (assuming complete ionizations)

$$p = \frac{N_i^2}{N} = \frac{10^{20}}{10^{6}}$$

$\overset{1}{.}00000000001$

$p = 10{,}000$ holes/cm^3

c) $$\rho = \frac{1}{q(N \cdot \mu_N + P \cdot \mu_P)}, \quad \mu_N = 600 \frac{cm^2}{V \cdot S}$$

$\Omega \cdot cm$

$$\rho = \frac{1}{1.6 \times 10^{-19} \cdot 10^{16} \cdot 600}$$

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d) $t = 5\,\mu m$, $L = 200\,\mu m$

$W = 10\,\mu$

$$R = \frac{\rho}{t} \cdot \frac{L}{W}$$

$5\,\mu$

0.0000050

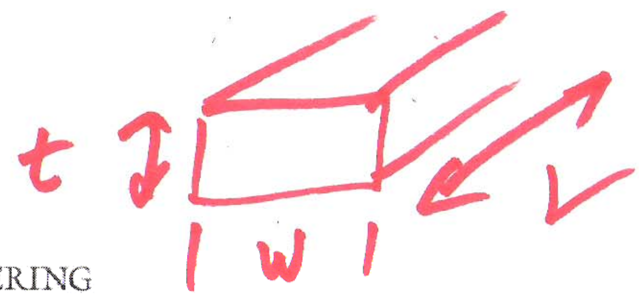
0.0005 cm

0.000005 m

$\times 10^{2} \cdot 10^{-2} \rightarrow c$

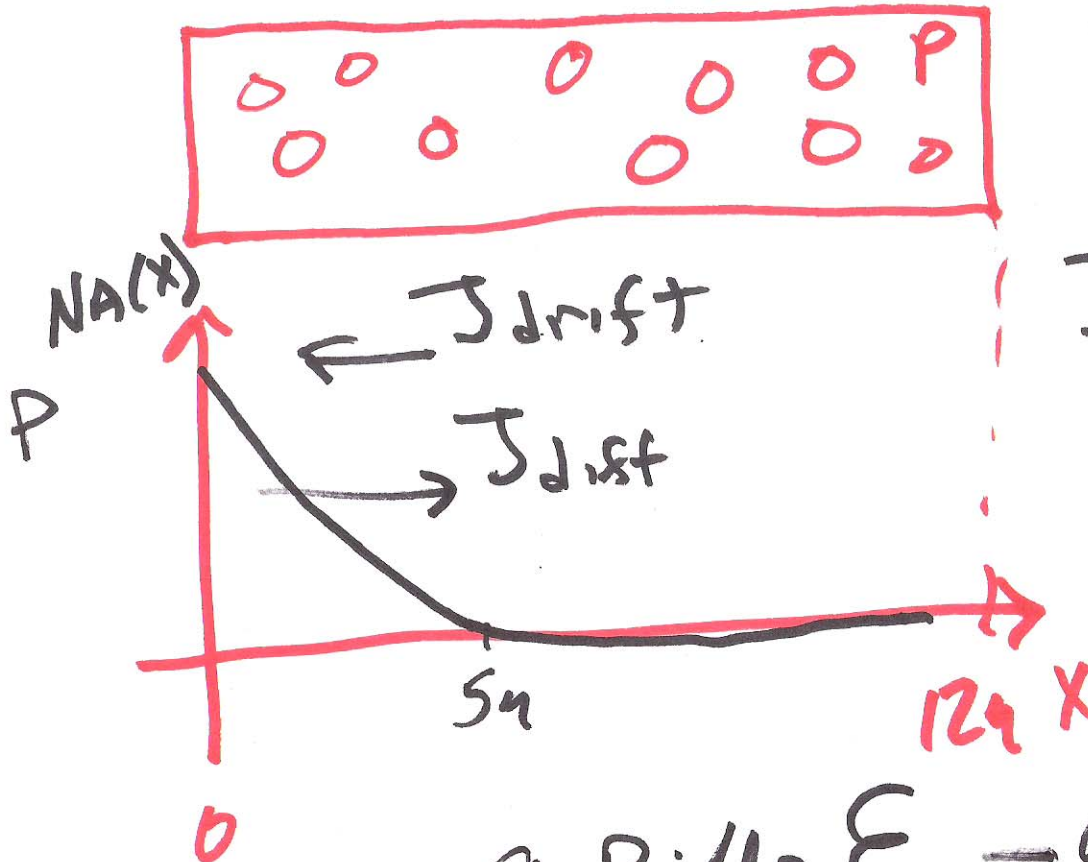
e) $$I = \frac{V}{R} = \frac{1}{R}$$

f) $$J = \frac{I}{A} = \frac{I}{w \cdot t}$$



2)

3.12) $N_A(x) = 10^{18} \cdot e^{-x/1\mu m} = p(x)$



$$\frac{dp}{dx} = \frac{10^{18}}{cm^3}\left(\frac{-1}{10^{-4}}\right) e^{-x/1\mu}$$

$$J_p = J_{drift} - J_{diff} = 0$$

$$q p \cdot \mu_p \mathcal{E} - q D_p \cdot \frac{dp}{dx} = 0$$

$$10^{18} e^{-x/10^{-6}} \cdot \mu_p \cdot E(x) = 0.025 \cdot \mu_p \cdot \frac{\left(-10^{-12} \cdot e^{-x/1\mu}\right)}{cm^3}$$

$$E(x) = \frac{-0.025 \cdot 10^{-12}}{10^{18} \cdot 10^{-4}\ cm}$$

$$= \frac{-0.025 \cdot 10^{-12}}{10^{14}\ cm} =$$

$$q \cdot p \cdot \mu_p \cdot \mathcal{E}(x) = q \cdot V_T \cdot \mu_p \cdot \frac{dp}{dx}$$

$$p = 10^{18} e^{-x/1\mu m} \text{ holes}/cm^3$$

$$\frac{dp}{dx} = \frac{10^{18}}{cm^3}\left(-\frac{1}{10^{-6}}\right) e^{-x/1\mu m}$$

$$\frac{10^{18} e^{-x/1\mu m}}{cm^3} \cdot \mathcal{E}(x) = 0.025 \frac{10^{18}}{cm^3}\left(-\frac{1}{10^{-6}}\right) e^{-x/1\mu}$$

$$\mathcal{E}(x) = -0.025 \cdot 10^6/m$$

$$= -25\ kV/m$$

$$= -250\ V/cm$$

5)

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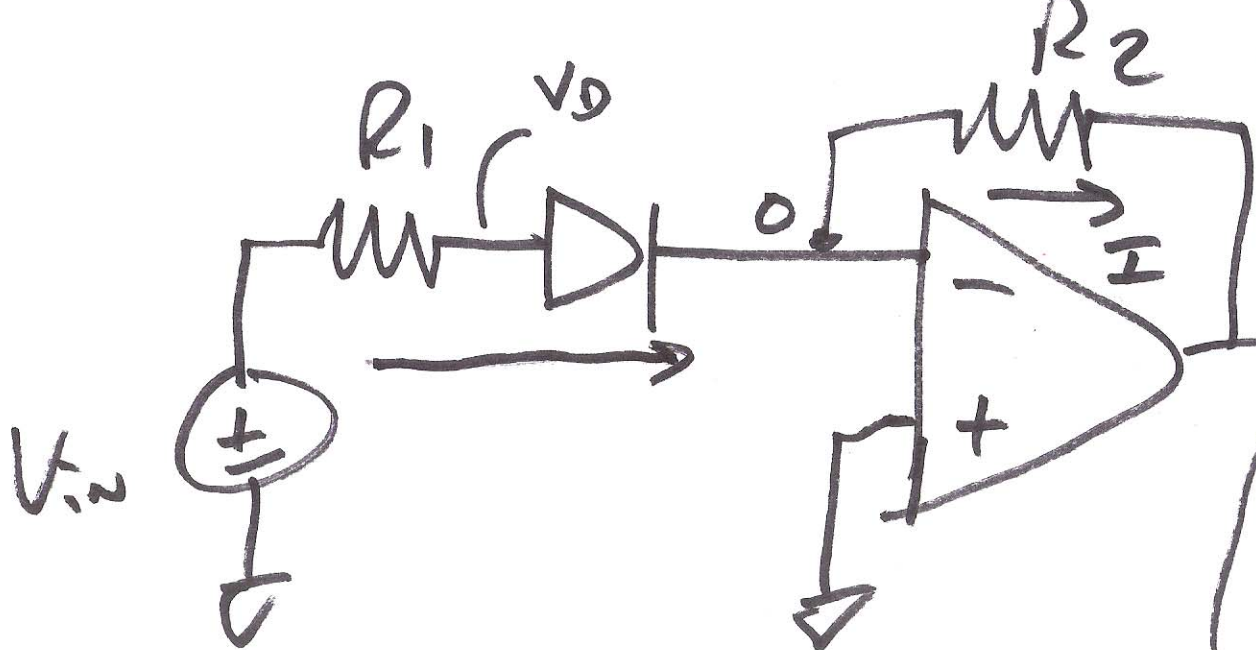


$$V_{OUT} = I \cdot R_2$$

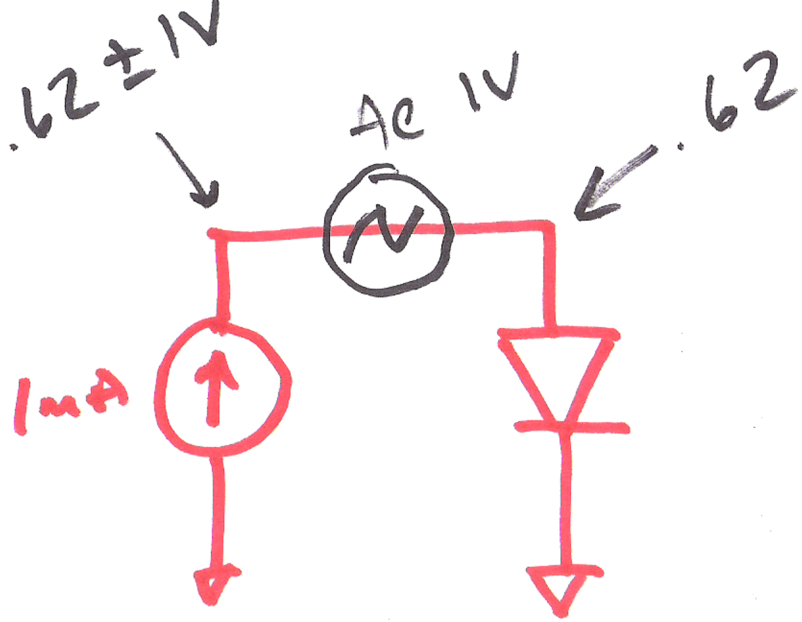
$$V_{IN} > 0$$

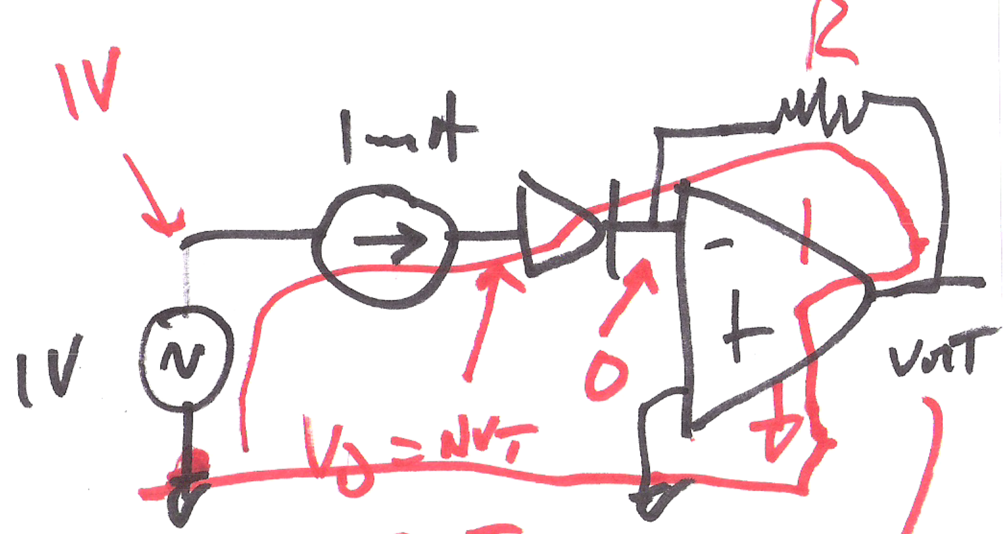
$$I_D = I_S e^{V_D/NV_T}$$

$$V_D = NV_T \ln \frac{I_D}{I_S}$$

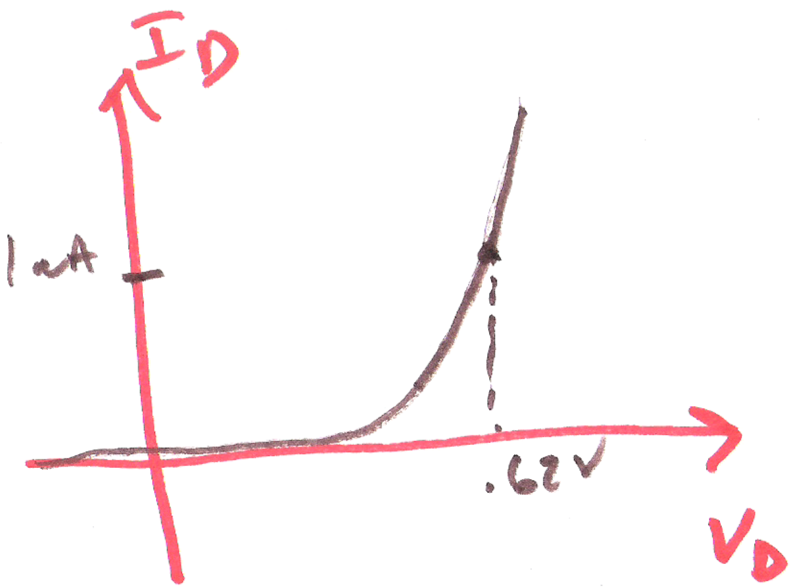
$$I = \frac{V_{IN} - V_D}{R_1}$$

$$= \frac{V_{IN} - NV_T \ln \frac{I_D}{I_S}}{R_1}$$

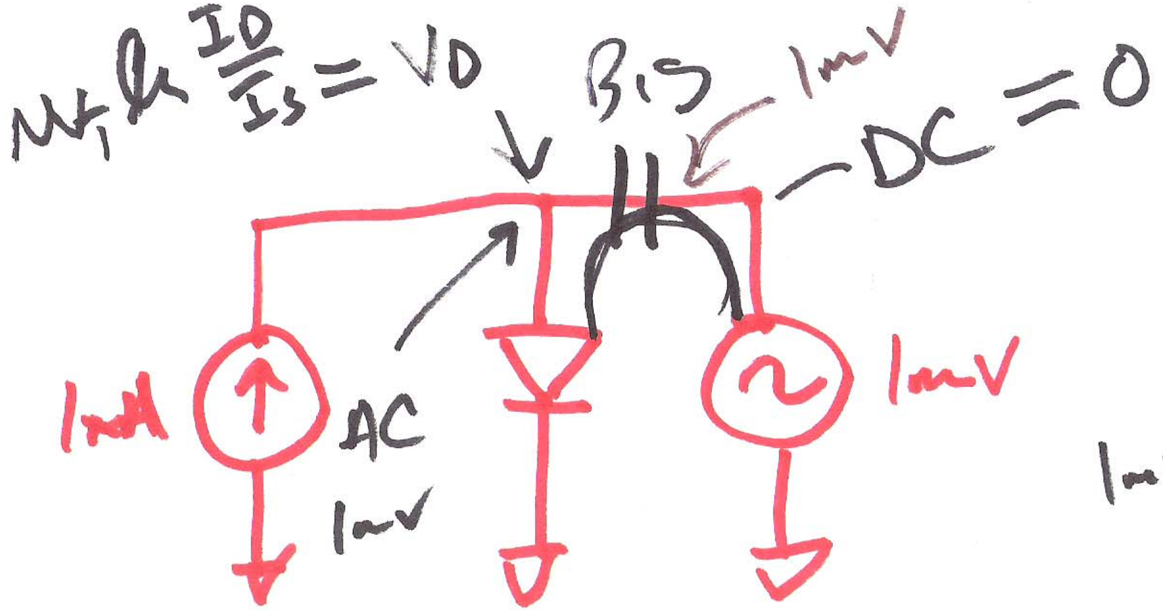


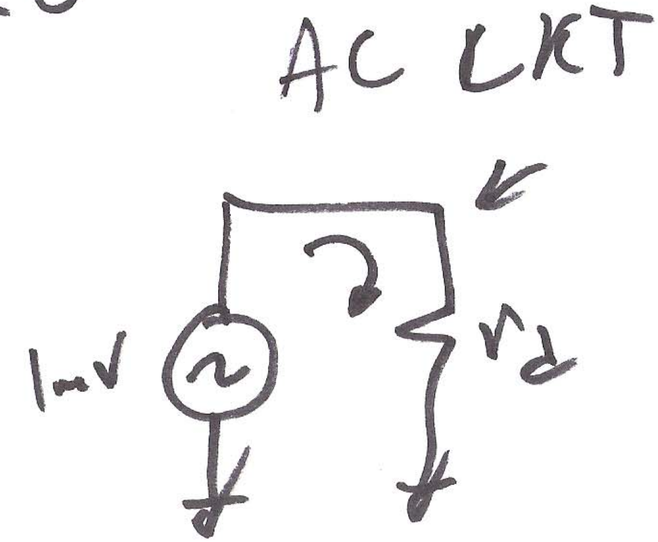


$$\ln \frac{I_D}{I_S} \approx 0.7$$

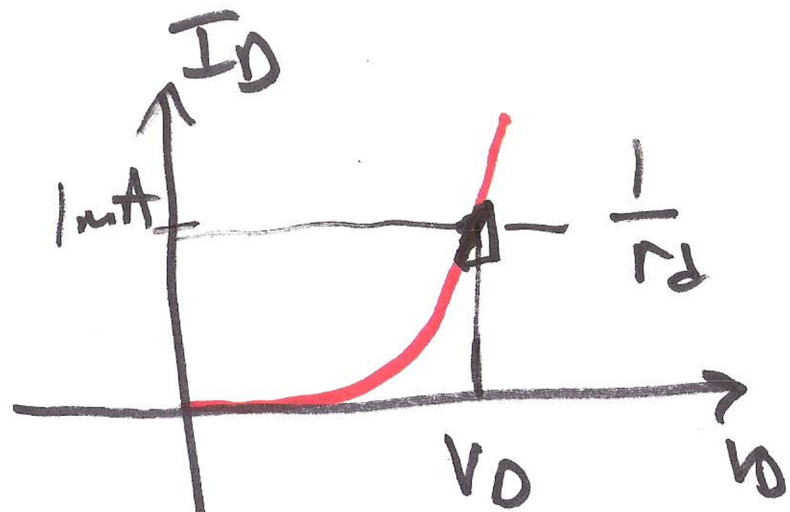


$$V_{OUT} = -1mA \cdot R$$

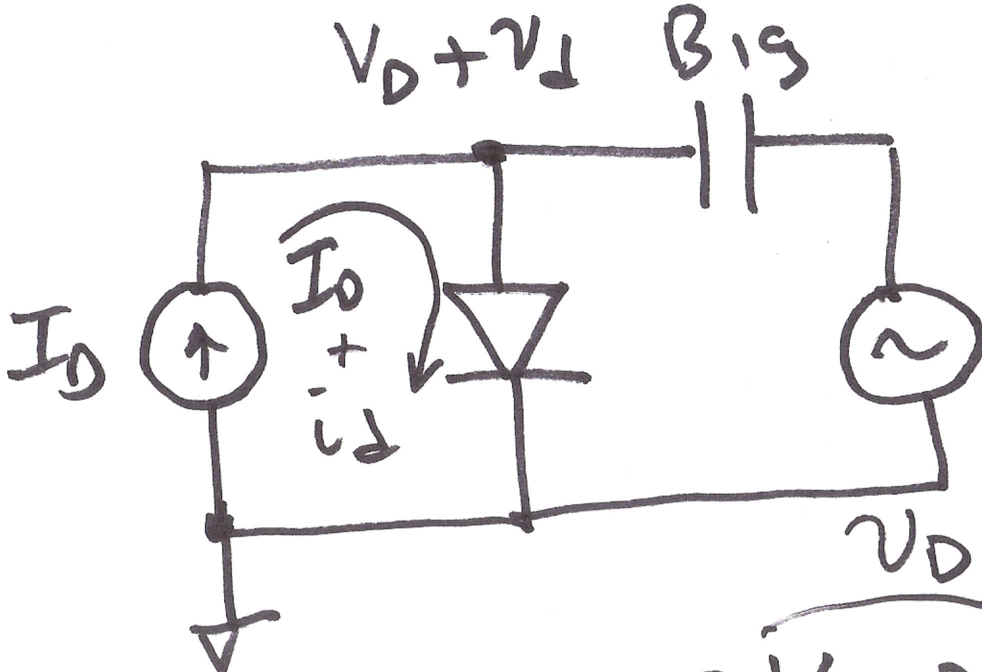




$$i_d = \frac{1mV}{r_d}$$



$$V_D = nV_T \ln \frac{I_D}{I_S}$$



$V_D + v_d = NV_T \ln \frac{I_D + i_d}{I_S}$

$\ln \frac{A}{B} = \ln A - \ln B$

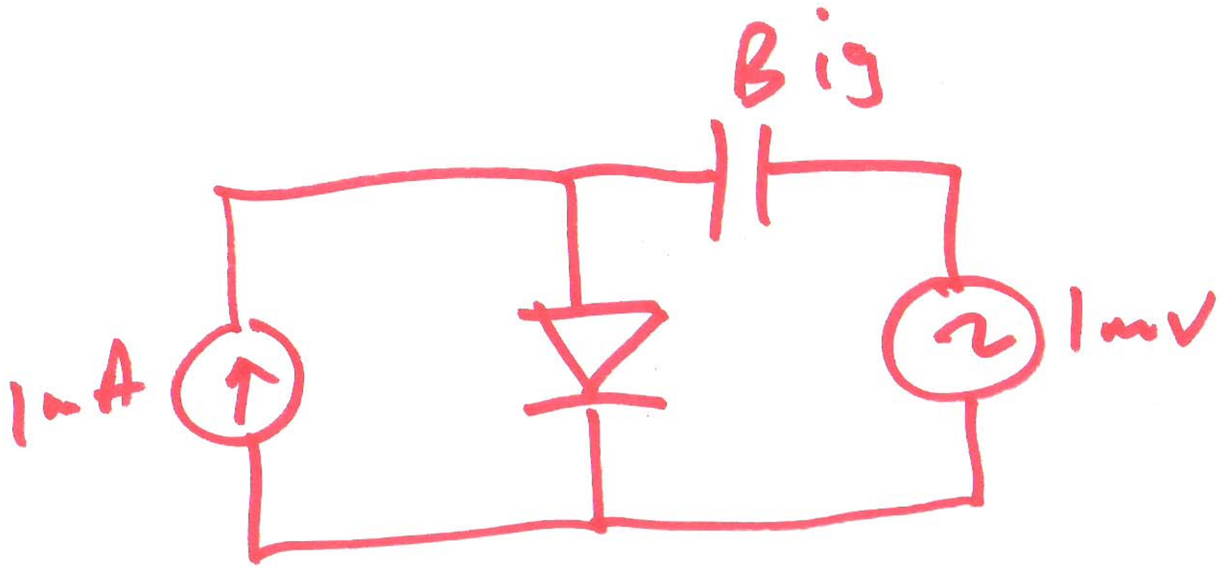
$r_d = \frac{\delta \overbrace{V_D + v_d}^{v_D}}{\delta i_D} \Big|_{\substack{I_D = \text{CONST} \\ V_D = \text{CONST}}} = \frac{NV_T}{I_D + i_d}$

$i_d \ll I_D$ small-signal

$i_D \to I_D + i_d$

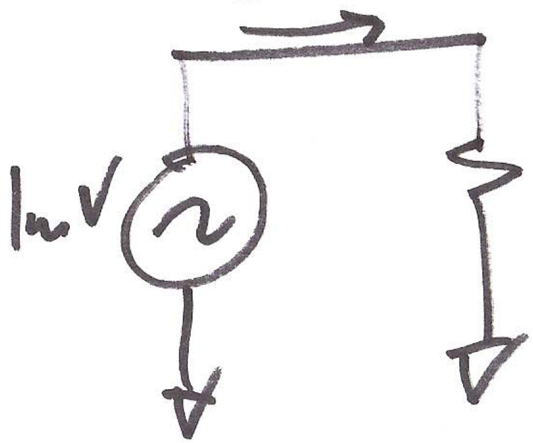
$\frac{d \ln x}{dx} = \frac{1}{x}$

$$\boxed{r_d \approx \frac{NV_T}{I_D}}$$



find AC current through the diode verify with sims.

$$i_d = \frac{1mV}{25\Omega} = 40\mu A$$



$$r_d = \frac{NV_T}{I_D} = 25\Omega$$